

new claims 23 - 50 is appropriate. The replacement claims have been amended from the PCT as shown in Exhibit B attached. No new matter is added to this case by these changes to the claims.

Respectfully submitted,

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EXHIBIT A

### Claims

1. A transducer element of a magnetic material for a torque or force sensor which comprises at least one annulus of magnetised material extending about an axis,  
 5 the at least one annulus being magnetised such that a closed loop of magnetic flux is established in the magnetic material,  
 the at least one annulus being responsive to a torque applied about said axis for a torque sensor or to  
 10 a bending moment acting about said axis due to an applied force for a force sensor, as the case may be, to emanate a magnetic field component externally of said element that is a function of the applied torque or the applied force, as the case may be, characterised in that:  
 15 the magnetisation established in the at least one annulus provides a torque-dependent magnetic field component which has a significant non-zero value at zero torque or force and an essentially zero value at a non-zero torque or force, as the case may be.
- 20 2. A transducer element as claimed in Claim 1 in which the at least one annulus is in the form of an annular ring attachable to a shaft, and the annular ring is of a magnetoelastic material and is circumferentially magnetised.
- 25 3. A transducer element as claimed in Claim 1 in which the at least one annulus is of magnetoelastic material and is a circumferentially magnetised, integral portion of a shaft.

4. A transducer element as claimed in Claim 1 in which the at least one annulus is longitudinally magnetised in the direction of said axis.

5. A transducer element as claimed in Claim 4 in which the at least one annulus is an integral portion of a shaft.

6. A transducer element as claimed in Claim 2 or 3 comprising a first annulus of magnetised material and a second annulus of magnetised material, wherein said first annulus provides an essentially zero value of magnetic field component at a non-zero torque or force of a given polarity and said second annulus provides an essentially-zero value of magnetic field component at a non-zero torque or force of the opposite polarity.

7. A transducer element as claimed in claim 4 or 5 comprising a first annulus of magnetised material and a second annulus of magnetised material, wherein said first annulus provides an essentially zero value of magnetic field component at a non-zero torque or force of a given polarity and said second annulus provides an essentially-zero value of magnetic field component at a non-zero torque or force of the opposite polarity.

8. A transducer element as claimed in Claim 1 in which said element has a surface extending radially of said axis and comprising a first annulus of magnetisation extending to said surface and a second annulus of magnetisation extending to said surface outwardly of said first annulus, said first annulus and said second annulus

being magnetised to provide a magnetic field component therebetween which has a significant non-zero value at zero torque or force, as the case may be, and an essentially zero value at a non-zero torque or force, as the case may be.

9. A transducer element as claimed in Claim 8 in which said first annulus is magnetised in the direction of said axis with a pole of given polarity at said surface and in which said second annulus is magnetised in the direction of said axis with a pole of opposite polarity at said surface.

10. A transducer element as claimed in Claim 8 in which said first annulus and said second annulus are each magnetised to form a respective closed loop of circumferential magnetisation, and the respective closed loops of circumferential magnetisation are of opposite polarity.

11. A transducer element as claimed in Claim 5 or Claims 7 and 5 comprising a respective further annulus of magnetisation located radially inwardly of the at least one annulus of magnetisation and longitudinally magnetised in the axial direction with a polarity opposite thereto to form a closed loop of magnetic flux therewith.

12. A transducer assembly comprising a transducer element as claimed in Claim 1 and a magnetic sensor arrangement oriented to detect said magnetic field component.

13. A transducer assembly comprising a transducer element as claimed in Claim 2 or 3 and a respective magnetic sensor arrangement for the at least one magnetised annulus and oriented to detect a magnetic field component in the direction of said axis.

14. A transducer assembly comprising a transducer element as claimed in Claim 4 or 5 and a respective magnetic sensor arrangement for the at least one magnetised annulus and oriented to detect a magnetic field component in the circumferential (tangential) direction about said axis.

15. A transducer assembly comprising a transducer element as claimed in Claim 6 and first and second magnetic sensor arrangements for detecting a respective magnetic field component emanated by said first annulus and said second annulus, each of said first and second magnetic sensor arrangements being oriented to detect a magnetic field component in the direction of said axis.

16. A transducer assembly comprising a transducer element as claimed in Claim 7 and first and second magnetic sensor arrangements for detecting a respective magnetic field component emanated by said first annulus and said second annulus, each of said first and second magnetic sensor arrangements being oriented to detect a magnetic field component in the circumferential (tangential) direction about said axis.

17. A transducer assembly comprising a transducer element as claimed in Claim 8 and a magnetic sensor

arrangement oriented to detect said magnetic field component provided between said first annulus and said second annulus.

18. A transducer assembly comprising a transducer  
5 element as claimed in Claim 9 and a magnetic sensor arrangement located to be responsive to the magnetic field between said first annulus and second annulus and oriented to detect a magnetic field component in the circumferential (tangential) direction about said axis.
- 10 19. A transducer assembly comprising a transducer element as claimed in Claim 10 and a magnetic sensor arrangement oriented to detect a radially directed magnetic field component between said first annulus and said second annulus.
- 15 20. A torque sensor system comprising a transducer assembly as claimed in Claim 15 or 16 responsive to torque applied about said axis, wherein said first and second magnetic field sensor arrangements provide first and second torque-dependent signals respectively, and  
20 further including signal processing means which comprises a first channel responsive to at least one of the first and second torque-dependent signals, said first channel comprising an output means having a controllable gain for producing an output signal representing a measure of  
25 torque, and which also comprises a second channel comprising means for combining the first and second torque-dependent signals to provide a reference signal, said output means being responsive to said reference

signal to adjust its gain in a sense acting to eliminate changes in the response relating the first and second torque-dependent signals with torque.

21. A torque sensor system as claimed in Claim 20 in  
5 which the combining means is operable to effect a difference operation on said first and second torque-dependent signals.

22. A torque sensor system as claimed in Claim 21 in  
10 which the first channel is responsive to both of said first and second torque-dependent signals to effect a summing operation thereon.

23. A method of forming a transducer element which is as  
claimed in any one of Claims 1 to 5 in which the  
magnetisation of said at least one annulus is performed  
15 while the transducer element is under a predetermined torque about said axis.

24. A method of forming a transducer element which is as  
claimed in Claim 6 or 7 in which the magnetisation of the  
first annulus is performed while the transducer element  
20 is under a predetermined torque of one polarity about said axis, and the magnetisation of the second annulus is performed while the transducer element is under a predetermined torque of the opposite polarity about said axis.

25. A method of forming a transducer element as claimed  
25 in Claim 6 or 7 in which the respective magnetisations of the first annulus and the second annulus are performed to provide magnetisations of opposite polarity.



26. A method as claimed in Claim 24 in which the magnetisations of the first annulus and the second annulus are of the same polarity.

27. A method as claimed in Claim 25 in which the  
5 magnetisation of the first annulus is performed under a predetermined torque of opposite polarity to that applied in the magnetisation of the second annulus.

28. A method of forming a transducer element which is as  
10 claimed in Claim 8, 9 or 10 in which the magnetisation of said first annulus and said second annulus is performed while said element is under a predetermined torque about said axis.

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# EXHIBIT B

Claims

23 1. A transducer element of a magnetic material for a torque or force sensor which comprises<sup>23</sup> at least one annulus of magnetised material extending about an axis,

5 the at least one annulus being magnetised such that a closed loop of magnetic flux is established in the magnetic material,

the at least one annulus being responsive to a torque applied about said axis for a torque sensor or to  
10 a bending moment acting about said axis due to an applied force for a force sensor, as the case may be, to emanate a magnetic field component externally of said element that is a function of the applied torque or the applied force, as the case may be, ~~characterised in that:~~

15 the magnetisation established in the at least one annulus provides a torque-dependent magnetic field component which has a significant non-zero value at zero torque or force and an essentially zero value at a non-zero torque or force, as the case may be.

24 20 2. A transducer element as claimed in Claim 1<sup>23</sup> in which the at least one annulus is in the form of an annular ring attachable to a shaft, and the annular ring is of a magnetoelastic material and is circumferentially magnetised.

25 25 3. A transducer element as claimed in Claim 2<sup>23</sup> in which the at least one annulus is of magnetoelastic material and is a circumferentially magnetised, integral portion of a shaft.

- 26 4. A transducer element as claimed in Claim 1 in which  
the at least one annulus is longitudinally magnetised in  
the direction of said axis. <sup>23</sup>
- 27 5. A transducer element as claimed in Claim 4 in which  
the at least one annulus is an integral portion of a  
shaft. <sup>26</sup>
- 28 6. A transducer element as claimed in Claim <sup>24</sup>~~2 or 3~~  
comprising a first annulus of magnetised material and a  
second annulus of magnetised material, wherein said first  
annulus provides an essentially zero value of magnetic  
field component at a non-zero torque or force of a given  
polarity and said second annulus provides an essentially-  
zero value of magnetic field component at a non-zero  
torque or force of the opposite polarity.
- 15 <sup>29</sup> 7. A transducer element as claimed in claim <sup>27</sup>~~4 or 5~~  
comprising a first annulus of magnetised material and a  
second annulus of magnetised material, wherein said first  
annulus provides an essentially zero value of magnetic  
field component at a non-zero torque or force of a given  
polarity and said second annulus provides an essentially-  
zero value of magnetic field component at a non-zero  
torque or force of the opposite polarity.
- 20 30 8. A transducer element as claimed in Claim 1 in which  
said element has a surface extending radially of said  
axis and comprising a first annulus of magnetisation  
extending to said surface and a second annulus of  
magnetisation extending to said surface outwardly of said  
first annulus, said first annulus and said second annulus

being magnetised to provide a magnetic field component therebetween which has a significant non-zero value at zero torque or force, as the case may be, and an essentially zero value at a non-zero torque or force, as the case may be.

31 <sup>30</sup> 9. A transducer element as claimed in Claim 8 in which said first annulus is magnetised in the direction of said axis with a pole of given polarity at said surface and in which said second annulus is magnetised in the direction of said axis with a pole of opposite polarity at said surface.

32 <sup>30</sup> 10. A transducer element as claimed in Claim 8 in which said first annulus and said second annulus are each magnetised to form a respective closed loop of circumferential magnetisation, and the respective closed loops of circumferential magnetisation are of opposite polarity.

33 <sup>27</sup> 11. A transducer element as claimed in Claim ~~5 or Claims~~ ~~3~~ ~~4~~ and 5 comprising a respective further annulus of magnetisation located radially inwardly of the at least one annulus of magnetisation and longitudinally magnetised in the axial direction with a polarity opposite thereto to form a closed loop of magnetic flux therewith.

25 <sup>34</sup> 12. A transducer assembly comprising a transducer element as claimed in Claim <sup>23</sup> 1 and a magnetic sensor arrangement oriented to detect said magnetic field component.

- 35 13. A transducer assembly comprising a transducer element as claimed in Claim <sup>24</sup>~~2~~-~~or~~-3 and a respective magnetic sensor arrangement for the at least one magnetised annulus and oriented to detect a magnetic field component in the direction of said axis.
- 36 14. A transducer assembly comprising a transducer element as claimed in Claim <sup>26</sup>~~4~~-~~or~~-5 and a respective magnetic sensor arrangement for the at least one magnetised annulus and oriented to detect a magnetic field component in the circumferential (tangential) direction about said axis.
- 37 15. A transducer assembly comprising a transducer element as claimed in Claim <sup>28</sup>~~6~~ and first and second magnetic sensor arrangements for detecting a respective magnetic field component emanated by said first annulus and said second annulus, each of said first and second magnetic sensor arrangements being oriented to detect a magnetic field component in the direction of said axis.
- 38 16. A transducer assembly comprising a transducer element as claimed in Claim <sup>29</sup>~~7~~, and first and second magnetic sensor arrangements for detecting a respective magnetic field component emanated by said first annulus and said second annulus, each of said first and second magnetic sensor arrangements being oriented to detect a magnetic field component in the circumferential (tangential) direction about said axis.
- 39 17. A transducer assembly comprising a transducer element as claimed in Claim <sup>30</sup>~~8~~ and a magnetic sensor

arrangement oriented to detect said magnetic field component provided between said first annulus and said second annulus.

- 40 18. A transducer assembly comprising a transducer  
5 element as claimed in Claim ~~9~~<sup>31</sup> and a magnetic sensor arrangement located to be responsive to the magnetic field between said first annulus and second annulus and oriented to detect a magnetic field component in the circumferential (tangential) direction about said axis.
- 10 41 19. A transducer assembly comprising a transducer  
element as claimed in Claim ~~10~~<sup>32</sup> and a magnetic sensor arrangement oriented to detect a radially directed magnetic field component between said first annulus and said second annulus.
- 15 42 20. A torque sensor system comprising a transducer  
assembly as claimed in Claim ~~15 or 16~~<sup>37</sup> responsive to torque applied about said axis, wherein said first and second magnetic field sensor arrangements provide first and second torque-dependent signals respectively, and  
20 further including signal processing means which comprises a first channel responsive to at least one of the first and second torque-dependent signals, said first channel comprising an output means having a controllable gain for producing an output signal representing a measure of  
25 torque, and which also comprises a second channel comprising means for combining the first and second torque-dependent signals to provide a reference signal, said output means being responsive to said reference

signal to adjust its gain in a sense acting to eliminate changes in the response relating the first and second torque-dependent signals with torque.

- 43 21. A torque sensor system as claimed in Claim <sup>42</sup>20 in  
5 which the combining means is operable to effect a difference operation on said first and second torque-dependent signals.
- 44 22. A torque sensor system as claimed in Claim <sup>43</sup>21 in  
10 which the first channel is responsive to both of said first and second torque-dependent signals to effect a summing operation thereon.
- 45 23. A method of forming a transducer element which is as  
15 claimed in any one of Claims <sup>23</sup>~~1 to 5~~ in which the magnetisation of said at least one annulus is performed while the transducer element is under a predetermined torque about said axis.
- 46 24. A method of forming a transducer element which is as  
20 claimed in Claim <sup>28</sup>~~6 or 7~~ in which the magnetisation of the first annulus is performed while the transducer element is under a predetermined torque of one polarity about said axis, and the magnetisation of the second annulus is performed while the transducer element is under a predetermined torque of the opposite polarity about said axis.
- 25 47 25. A method of forming a transducer element as claimed  
in Claim <sup>28</sup>~~6 or 7~~ in which the respective magnetisations of the first annulus and the second annulus are performed to provide magnetisations of opposite polarity.



- 48 26. A method as claimed in Claim <sup>46</sup>24 in which the magnetisations of the first annulus and the second annulus are of the same polarity.
- 49 27. A method as claimed in Claim <sup>47</sup>25 in which the  
5 magnetisation of the first annulus is performed under a predetermined torque of opposite polarity to that applied in the magnetisation of the second annulus.
- 50 28. A method of forming a transducer element which is as  
claimed in Claim <sup>30</sup>~~8, 9 or 10~~ in which the magnetisation of  
10 said first annulus and said second annulus is performed while said element is under a predetermined torque about said axis.